Clustering Uniformity Methods for Energy Efficiency in Wireless Sensor Networks

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Abstract – The wireless sensors that make up a wireless sensor network (WSN) are randomly deployed in nature and cannot be artificially replaced when their batteries are depleted. Failure of communication connection between wireless sensors causes continuous connection attempts, which results in a lot of power dissipation and shortens the lifetime of the WSN. In this paper, we propose to extend the lifetime of WSNs by limiting the appropriate distance between the cluster head (CH) node and the communicating sensor nodes (SNs) so that a group of clusters of appropriate size can be formed on a two-dimensional plane. To equalize cluster size, sensor nodes with the shortest distance communicate with each other to form member nodes, and nodes with closer distances are brought together to form clusters. The simulation results show the improvement rate of cluster uniformity over the shortest distance-based clustering method for clustering based on the proposed cluster uniformity algorithm. The proposed method can improve the cluster uniformity of the network by about 20%. In addition, the power consumption of the proposed method is analyzed according to the difference in the density of sensor nodes in the cluster groups to examine the improvement in power consumption.

Keywords – Wireless Sensor Networks, Cluster Uniformity, Battery Power, Lifespan, Multi-Hop, Cluster Head, Sensor Nodes.

I. INTRODUCTION

Wireless sensor networks (WSNs) use a variety of sensor devices to monitor the physical state of the surrounding environment in various harsh natural environments [1]. Due to the sensor nodes that make up a WSN operate on limited power, they must be able to operate in an energy-efficient manner throughout their lifetime [2,3]. Advances in semiconductor technology have enabled the miniaturization of sensor technology, leading to the development of microelectromechanical systems (MEMS) sensors capable of low-power operation, which have played a revolutionary role in extending the lifetime of sensors [4]. Wireless sensor networks randomly distribute sensors over wide areas that are not uniformly distributed due to geographical conditions. The clusters formed in a network with unevenly distributed sensors have different densities of sensor nodes in each cluster. The existing clustering technology does not consider the distribution density of the sensors that make up the network. In the real network environment, the distribution of sensor nodes may not be uniform due to the characteristics of the natural environment [5, 6]. Clusters created in networks with unevenly distributed sensors have different densities of sensor nodes. This leads to differences in energy consumption when a cluster head (CH) node collects data from its member sensor nodes and transmits it to its neighboring cluster heads. In traditional absolute hop-based clustering schemes, when a cluster head (CH) node collects data from its member sensor nodes and transmits it to the destination, the unevenness of sensor node density leads to differences in the energy consumption of each CH node. A CH node in a cluster with a high sensor node density will consume more energy than a cluster with a relatively low sensor node density. CH nodes in clusters that consume more energy will have a shorter lifetime, which in turn reduces the lifetime of the network. When the CH node's battery is depleted, the CH node must be selected and replaced from among the other SN nodes in the cluster. If this process occurs frequently, the battery life of all member nodes in the cluster is reduced [7]. When a CH node's battery is depleted, it cannot collect data from its member sensors or transmit it to its destination. Therefore, another sensor node among the member nodes must be elected as the new cluster head node. The shorter the interval between CH node replacements, the faster the lifetime of the cluster will decrease, which in turn reduces the lifetime of the entire network [8, 9]. The LEACH algorithm does not consider the amount of energy used by sensor nodes and their locations. As a result, sensor nodes may experience early battery depletion, leading to a shortened lifespan of the Wireless Sensor Network (WSN) [10, 11].

In this paper, a clustering method based on the LEACH routing protocol is proposed. This paper proposed a clustering technique that can regenerate sensor nodes of different densities in WSNs into clusters of similar size to maintain a uniform density of sensor nodes within a cluster. By creating clusters based on the distance between sensor nodes, the proposed algorithm achieves a proper density distribution of sensor nodes, which improves the uniformity of the existing cluster size by about 20%. In addition, the power consumption of the uniformized cluster group proposed in this paper and the power consumption of the cluster group before uniformization are analyzed to examine the improvement in power consumption.

II. A RADIO CHANNEL MODEL

It is more energy efficient to transmit data from sensor nodes through CH nodes than directly to the destination. The LEACH scheme is proposed to reduce energy consumption by electing CH nodes to transmit data to the sink node and adopts a single-hop clustering method [12].

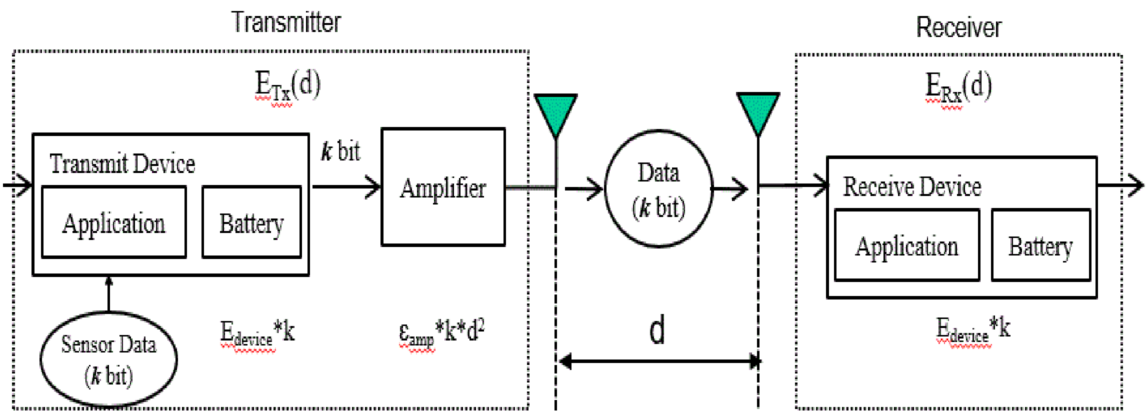


Fig 1. Radio Energy Model Between Transmit and Receive Nodes.

The transmitter/receiver model is assumed as shown in **Fig 1**, with $\boldsymbol{E_{device}}$ = 50 nJ/bit and $\boldsymbol{\epsilon_{amp}}$= 100 pJ/bit/$\boldsymbol{m^2}$ for the transmitter/receiver model [13]. The wireless model for transmitting k bits of information over a distance d is as follows:

$$\boldsymbol{E_{Tx}}(k, d) = \boldsymbol{E_{Tx-device}}\ (k) + \boldsymbol{E_{Tx-amp}}\ (k, d)$$

$$\boldsymbol{E_{Tx}}\ (k, d) = \boldsymbol{E_{device}} * k + \boldsymbol{\epsilon_{amp}} * k * \boldsymbol{d^2} \tag{1}$$

The wireless model for receiving a k-bit message from a transmitting node is modelled as follows [14]:

$$\boldsymbol{E_{Rx}}\ (k, d) = \boldsymbol{E_{Rx-device}}\ (k)$$

$$\boldsymbol{E_{Rx}}\ (k, d) = \boldsymbol{E_{device}} * k \tag{2}$$

The total energy consumption of a cluster group depends on the size of the generated cluster.

III. RELATED WORK

There are two basic approaches to clustering: distributed clustering and centralized clustering. In distributed clustering, each sensor node can make a decision to become a cluster head by a clustering algorithm. In centralized clustering, nodes are grouped by a central control center to form clusters and cluster heads. There are also hybrid methods that are a mix of distributed and centralized.

When forming clusters, clusters can be formed according to the internal structure of the cluster. When forming a cluster group, it can be formed according to the number of clusters, and the larger the number of clusters, the smaller the size of the cluster distribution, which is more beneficial in terms of energy consumption. The cluster heads can be pre-assigned by the deployed sensor nodes to form a fixed cluster, or the cluster heads can be randomly selected to form a variable number of clusters. Cluster size refers to the maximum path length between member nodes from the cluster head. A smaller cluster size minimizes the transmission distance for data collection from the sensor nodes at the cluster head, resulting in lower energy consumption. In addition, cluster density is defined as the ratio of the number of cluster members in a cluster to the cluster area. Higher cluster density increases the energy consumption of the cluster head. Minimizing energy consumption is an important factor.

When deploying a vast number of sensor nodes, the high cost of maintenance needs to be mitigated [15]. Other key issues in WSNs [16] include efficient data transmission to the sink node, proper congestion management, and low packet loss rates. The LEACH clustering algorithm [17] studied various factors that affect the location and distance of the network based on the distance between sensor nodes in a cluster. Researchers [18] presented an energy efficient cluster model called EECS. This model is favorable for large sensor networks as it collects data periodically. The proposed scheme selects a cluster header from the sensor nodes in the cluster group. The cluster head is selected through a competition among sensor nodes within the transmission radius of the nodes. They also proposed a WSN partitioning algorithm based on k-nearest neighbor algorithm (KNN) for cluster group formation [19], where each sensor node interacts directly with the cluster in which it is located and with the base station (BS). A reliability derivation process for energy-efficient and reliable WSN-based Internet of Things connectivity was proposed for data collection from sensed nodes in a cluster [20]. The system used risk strategy analysis to determine ideal recommendations to reduce communication load while increasing efficiency. The energy-aware approach reduces network latency while providing sufficient security.

Cluster Group Formation

In wireless sensor networks, sensors are randomly deployed over a large area in the wild, and then neighboring sensors communicate with each other to form clusters. When a large number of sensors are randomly distributed in various geographical environments, the sensors are unevenly distributed, and when uneven density of sensors form clusters, clusters of different sizes are formed. Since sensors within a single hop distance communicate with each other to form cluster members, and these member nodes form a cluster, the number of sense node members in a cluster formed under high sensor density conditions is higher than in other clusters. **Fig 2** shows the simulation result of randomly distributed sensor nodes forming a cluster by adding communicating nodes within a unit distance as member nodes. This simulation result assumes that about 3000 sensor nodes are deployed within a 100X100 unit distance (1 unit is the minimum distance between orthogonal and diagonal positions of sensor nodes). The red color represents the CH node, and each member node in the cluster is connected to the CH node in green. Black dots represent sensor nodes. As you can see in the figure, when the density of member nodes is high on a two-dimensional plane (when the neighboring nodes are close together), each sensor node has more members to add as neighbors, and a large cluster group is formed. The geographical locations of sensor nodes are simplified to unit distance along the x and y axes, i.e., a distance of +1 along the x axis means that they are neighbors by 1 unit distance. As you can see from the cluster formation example in **Fig 2**, the density of sensor nodes is not constant because they are randomly distributed in a certain area, so the size of the clusters formed varies greatly. The red dotted areas in the figure are clusters A to K, which are significantly different from the density of sensor nodes in other groups. The difference in sensor node density is adjusted by a parameter. The energy consumption of sensor nodes can be reduced by adjusting the cluster size not to be too large to prevent communication failure between sensor nodes and CH nodes in the cluster [21, 22, 23].

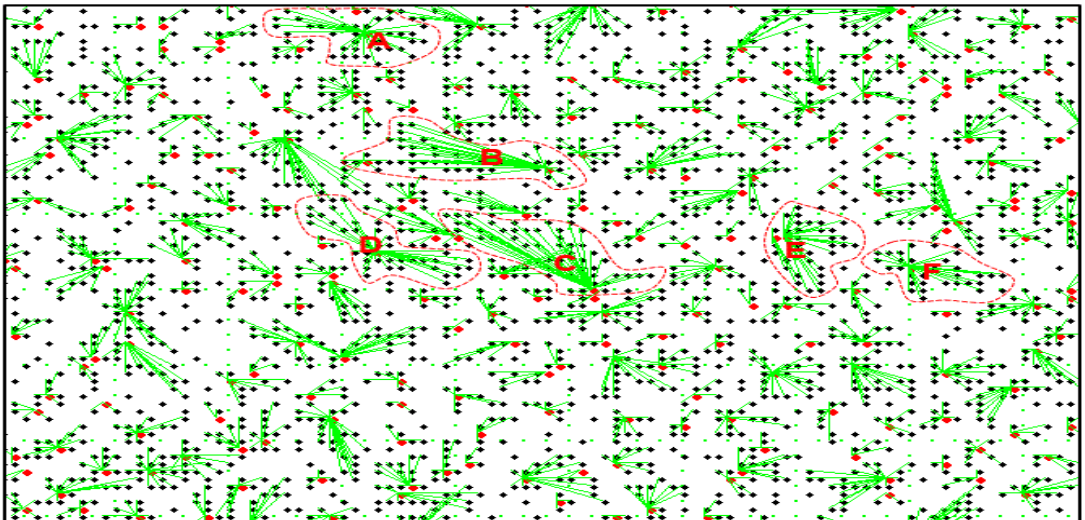


Fig 2. Example Of Forming a Cluster Within A 100X100 Unit Distance.

Cluster Uni-Formation

IV. CLUSTER GROUP HOMOGENIZATION – CLUSTERING

Since the sensors are randomly deployed over a large area in harsh weather conditions, the sensors are distributed in different densities on a three-dimensional plane. Therefore, some of the clusters formed from the deployed sensors have a high-density distribution and some have a low-density distribution. Sensor nodes communicate with the cluster head (CH) node to send data to the CH nodes in the cluster group of which they are a part, and as the size of the cluster increases, the amount of data that needs to be collected from the member nodes in the cluster increases, resulting in higher battery consumption and shorter lifespan of the CH node. Faster battery drain on the CH node reduces its lifespan, causes frequent CH node elections from member nodes in the cluster, and can quickly reduce the lifespan of all member nodes in the cluster. Therefore, if one cluster is larger than the others, you may want to partition the cluster to even out the size of the cluster.

Fig 3 shows the group formation process of randomly placed sensor nodes. It shows the process of neighboring sensor nodes attracting each other to form a group. For the node at coordinate d(4, 4), the pulling forces on both sides are similar, but it will eventually belong to the group with the stronger pulling force. As a result, three groups are formed and the node at coordinate (4, 4) is registered as a member of group B. In this way, we can apply interaction forces between nodes and apply them to neighboring nodes to form clusters. Cluster formation consists of two steps. First, among the randomly scattered sensor nodes, we find nodes with a distance of 1 (1D) between each node. Once nodes with a distance of 1 are found, they communicate with each other and record an ID number on each node for identification. In this study, we limit the distance between nodes affected by mutual attraction to 1D, but it can be extended beyond 1D.

In order to reduce the density of sensor nodes, we do not add all sensor nodes within a unit distance as member nodes but add nodes with the strongest physical mutual attraction per unit distance as member nodes. At this time, a sensor node is assumed to be a single object, and a cluster group is formed based on the fact that if the distance between objects is close, the attraction force (mutual attraction) between them is large. An example of the process of dividing clusters by adding nodes with the strongest mutual attraction within a unit distance as members of the same cluster is shown in **Fig 4**. **Fig 4** is an example of sensor node placement. The number in the node is the number of adjacent nodes within a unit distance. A higher number means more adjacent nodes and a stronger physical connection between nodes. The unit distance is assumed to be one space on the x and y axis, and one space on the diagonal is also included as a unit distance. In the example of Group 1 shown in a) of **Fig 2**, Group 1 was formed as one cluster group by nodes connected by unit distance, but considering the mutual attraction between nodes, two small groups were formed and can be divided into two clusters (Group 1-1, 1-2) as shown in b). Similarly, the cluster Group 2 in c) can be divided into two server groups (Group2-1, 2-2) as shown in d) by applying the mutual attraction of sensor nodes connected by a unit distance. The simulation result of the cluster groups generated in **Fig 2**, which are separated into lower density cluster groups by re-forming the cluster groups for the higher density cluster groups, is shown in **Fig 4**. **Fig 4** is the result of the cluster equalization task completed in the entire network.

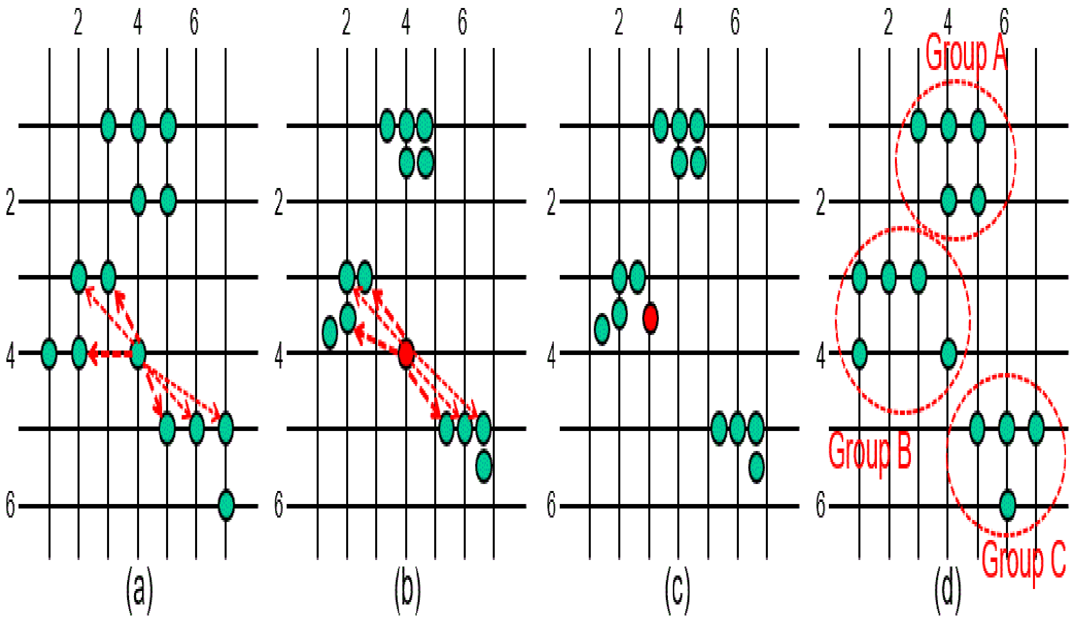


Fig 3. Example Of Grouping Formation.

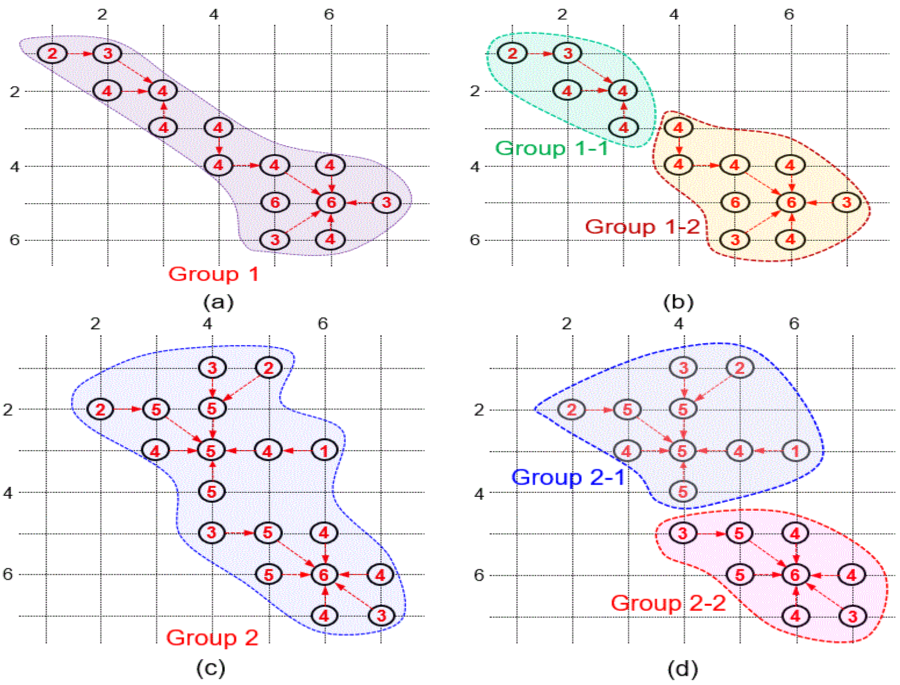


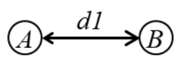
Fig 4. Example Of a Created Group Split into Two Groups.

Cluster Generation

A cluster group is formed by nodes that are located in close proximity to each other communicating with each other to form cluster members. To complete the formation of a cluster, a cluster group is formed by electing a cluster head (CH) from among the cluster group member nodes. If the number of member nodes in a cluster group is too large, the cluster group is divided into appropriate sizes to re-form the cluster group. In order to keep the size of the cluster group below a certain number, nodes that are adjacent to each other at a unit distance between sensor nodes should be prioritized for membership.

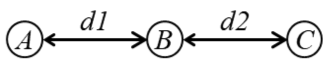
Distance Based Member Nodes Extract

The presented clustering algorithm organizes cluster members based on distance. Clustering is formed based on the mutual attraction between nodes that physically attracts them to each other as a function of distance. We define the strength of the interaction force as a function of distance as $\boldsymbol{f}_{AB}$ (from node A to B). If nodes A and B are within unit distance d1, set d1=1, otherwise set d1=0.



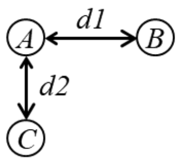
$f_{AB} = 1/d1$ *case 1*

Define the unit distance between two nodes (A-B) as d1, and the force of attraction between them as a force inversely proportional to the distance. Assuming that there are three neighboring nodes, there are two types of nodes that can be formed with unit distance in the x-axis and y-axis directions (case 2 and 3). In case 2 below, we define that node A and node B are within unit distance if the distance between them is d1=1. Node C is not within unit distance of node A, so it cannot be a member node, but if node C is within unit distance of node B, then set d2=1 and nodes B and C are member nodes. Consequently, nodes A, B, and C are member nodes.



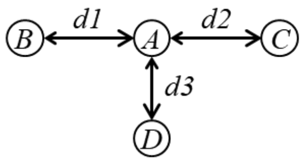
$\boldsymbol{f}_{AB}$ = 1/d1, $\boldsymbol{f}_{BC}$ = 1/d2, $\boldsymbol{f}_{AC}$ = 1/(d1+d2 *case 2*

When neighboring nodes are placed as shown in case 3 below, set d1=1 and nodes A and B are member nodes in the same way as before, with node B within unit distance of node A. If node C is also within a unit distance of node A, set d2=1 and nodes A and C are member nodes. Therefore, nodes A, B, and C become member nodes. Nodes B and C will not be added as member nodes because their unit distance is greater than 1, but nodes A, B, and C will be member nodes because nodes A and C and nodes A and B are member nodes.



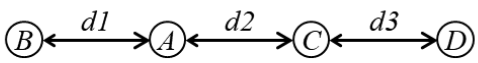
$$f_{AB} = 1/d1,\ f_{AC} = 1/d2\ ,\ f_{BC} = 1/\sqrt{d1^2 + d2^2} \qquad \textit{case 3}$$

When the number of adjacent nodes is expanded to 4, the form of nodes that can be formed is the same as Case 4-7. In case 4 below, if d1=d2=d3=1, then node B and node C will be added as member nodes for node A. Also, D is added as a member node for node A. Therefore, nodes A, B, C, and D are member nodes.



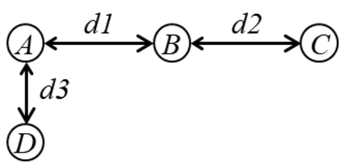
$$f_{AB} = 1/d1,\ f_{AC} = 1/d2\ ,\ f_{AD} = 1/d3\ ,\ f_{BC} = 1/(d1+d2),\ f_{BD} = 1/\sqrt{d1^2 + d3^2},\ f_{CD} = 1/\sqrt{d2^2 + d3^2} \qquad \textit{case 4}$$

In case 5 below, if d1=d2=d3=1, then node B is added as a member node for node A, node C is added as a member node for node A, and node D is added as a member node for node C. In conclusion, nodes A, B, C, and D are connected to each other by a unit distance and are therefore member nodes.



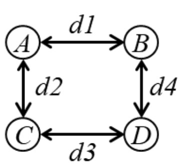
$$f_{AD} = 1/(d2+d3),\ f_{BC} = 1/(d1+d2),\ f_{BD} = 1/(d1+d2+d3 \qquad \textit{case 5}$$

For case 6 below, if d1=d2=d3=1, then node B and node D are member nodes for node A, and node C is added as a member node for node B. Thus, nodes A, B, C, and D are member nodes.



$$f_{BD} = 1/(\sqrt{d1^2 + d3^2}),\ f_{CD} = 1/(\sqrt{d3^2 + (d1 + d2)^2} \qquad \textit{case } 6$$

In case 7 below, if d1=d2=d3=d4=1, then A, B, C, and D are member nodes for the same reason.



$$f_{AD} = 1/(\sqrt{d1^2 + d4^2}) = 1/(\sqrt{d2^2 + d3^2})\ ,\ f_{BC} = 1/(\sqrt{d1^2 + d2^2}) = 1/(\sqrt{d3^2 + d4^2}) \qquad \textit{case } 7$$

By extending the placement of nodes like case1 to case7, we can consider different types of neighbors.

Cluster Formation Algorithm

The algorithm for forming cluster groups in the distance-based model presented in the previous section is as follows.

P1. Every sensor node sends a broadcast message containing latitude and longitude information to its neighbors for cluster group membership registration.

P2. Each sensor node receives broadcast messages from its neighbors. It registers the first received message first and calculates the distance from the GPS information.

p3. To register only sensor nodes that exist within a unit distance, it sends a group membership request message to the sensor node that sent the message about the nodes that exist within the unit distance.

p4. Sends an acknowledgement message from the node that requested membership.
p5. If the node receives the approval message, the node registers itself as a member.
By performing the above P1 to P5 process, the group formation for all sensor nodes is completed.

Cluster Head (CH) Node Election

After cluster group formation is complete, each cluster group must elect a Cluster Head (CH) node. Among the members in the cluster group, find the node with the maximum connectivity among the nodes and elect it as the CH node. The process of electing a CH node in a formed cluster is as follows.

p6. For every node in the group, each sensor node counts the number of connected nodes within a unit distance between member nodes. The higher the number of connected nodes, the stronger the connection between the nodes.

P7. Remove the nodes with the weakest connectivity one by one to find the nodes with the strongest connectivity in the group.

P8. Repeat P6 until there are no neighboring nodes.

P9. The last remaining node is elected as the CH node and broadcasts the CH node to its members.

p10. All member nodes register as CH.

The CH node selection is completed by procedures p6-p10. **Fig 5** illustrates the process of selecting a CH node among cluster members on the example of a cluster. It shows the process of excluding cluster members one by one in steps (a) to (g) for a specific cluster group, In conclusion, the member node corresponding to the (3,4) coordinate in **Fig 5-**(a) is selected as the CH node.

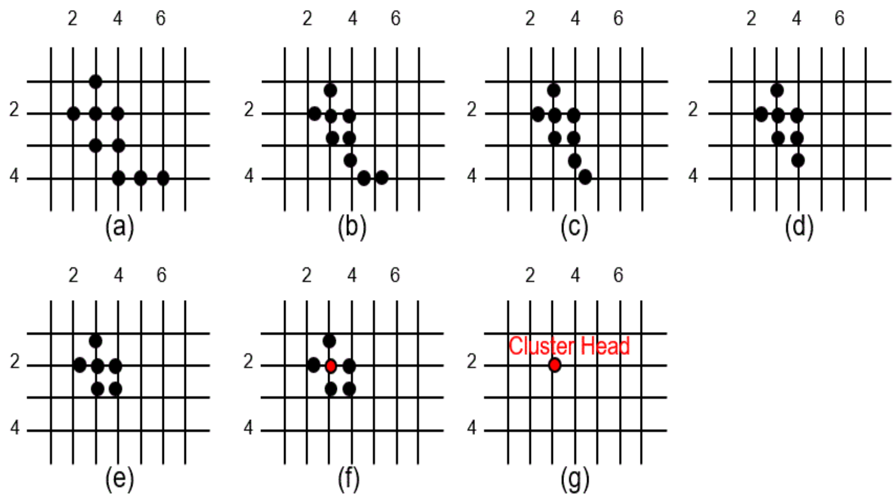


Fig 5. Example Of CH Node Election**.**

Simulation Method

The results of cluster homogenization were confirmed through simulation. In the simulation, nodes located at a unit distance between sensor nodes are formed into the same cluster group, and a CH node is selected from within the group, and the CH node and the member nodes in the group are displayed as solid lines to indicate that they are members of the same group. In **Fig 1**, the dense cluster group is divided into smaller cluster groups as shown in **Fig 6**, and the degree of uniformity is compared and shown in **Fig 6**. The simulation results were implemented in a Java program.

Simulation Results

A uniformization simulation of the cluster group formed when sensor nodes are randomly distributed over a distance of 100x100 units is shown in **Fig 6**. Compared to cluster groups A to I in **Fig 2**, the re-formed cluster group is separated into smaller cluster groups after uniformization is applied. In **Fig 2**, the red dots represent the CH nodes elected in the cluster group, and the connections between CH nodes and member nodes are depicted by green dashed lines, representing the member nodes communicating with the CH nodes. In **Fig 6**, the red dots represent CH nodes, and the blue solid lines indicate the member nodes that can communicate with the CH nodes. The light blue dots indicate the state that is not formed as a group, and the connection strength is adjusted to form a group.

Fig 7 shows the comparison results before and after cluster homogenization. The x-axis shows the number of sensor nodes in a cluster group, and the y-axis shows the number of cluster groups with that number of sensor nodes, and is the cumulative average of the results of more than 100 simulations. It can be seen that the density of sensor nodes in a cluster group is more than 20% lower than before cluster homogenization. The figure illustrates that as the number of members within a cluster group increase, it tends to split into smaller cluster groups. It can be observed that after the group has more than 31 members, it mostly dissipates into smaller clusters

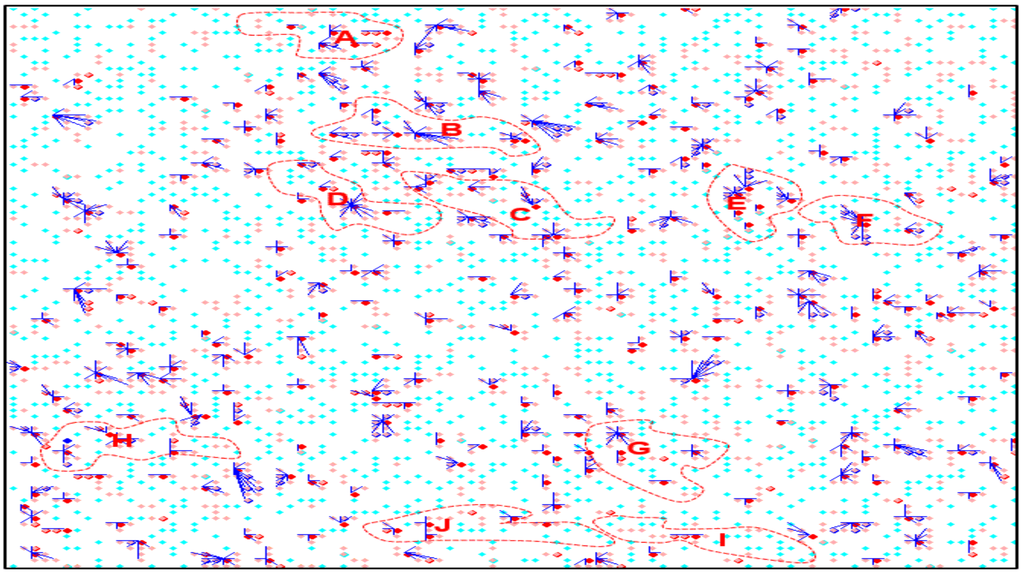


Fig 6. Simulation Results of Cluster Homogenization.

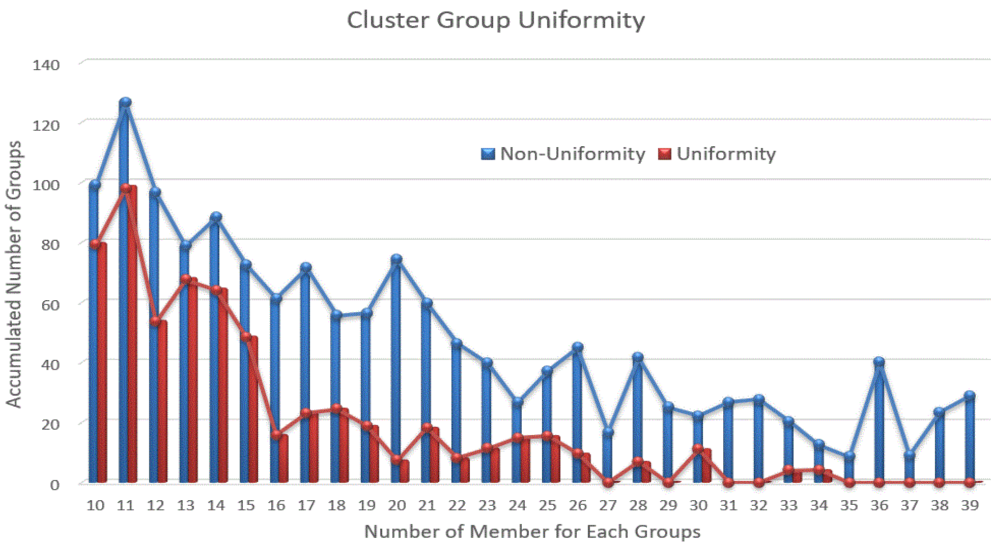


Fig 7. Cluster Non-Uniformity Vs. Uniformity Comparison.

Cluster Heads Vs. Energy Consumption

The CH node collects data from sensor nodes within the group. It is more energy efficient for a CH node to collect data from member nodes and transmit it to the destination than for each member node to transmit data directly to the destination (sink node). When each member node in the group transmits data to the CH node once, the CH node receives data equal to the number of member nodes. Therefore, CH nodes consume more energy than member nodes [13, 14]. If the cluster group is large, the CH node in the group needs to collect data from relatively more sensor nodes than the CH node in a small cluster group. In other words, a cluster group with a high density of sensor nodes is formed with many sensor nodes as members, and the CH node elected within it consumes more power because it needs to collect data from many sensor nodes and forward it to the sink node. Therefore, it consumes power faster and replaces the CH node more often. The shorter the interval between CH node replacements, the higher the power consumption due to replacement, which in turn quickly reduces the lifetime of all sensor nodes in the cluster group.

We examined the low-power consumption associated with the uniformization of cluster group density. Different levels of cluster density were distinguished for the same group, and the power consumption of CH nodes was calculated. The cluster group model is shown in **Fig 8**. It was divided into three levels based on cluster group density, denoted as a) to c), where a) has 10 members, b) has 20 members, and c) has 30 members, with b) having twice the density of a) and c) having three times the density of a). The red nodes represent CH nodes. Members located within a unit distance (d=1) from the CH node form a single cluster group centered around the CH node. This expands into b) with a unit distance of d=2 and further expands into c) with a unit distance of d=3.

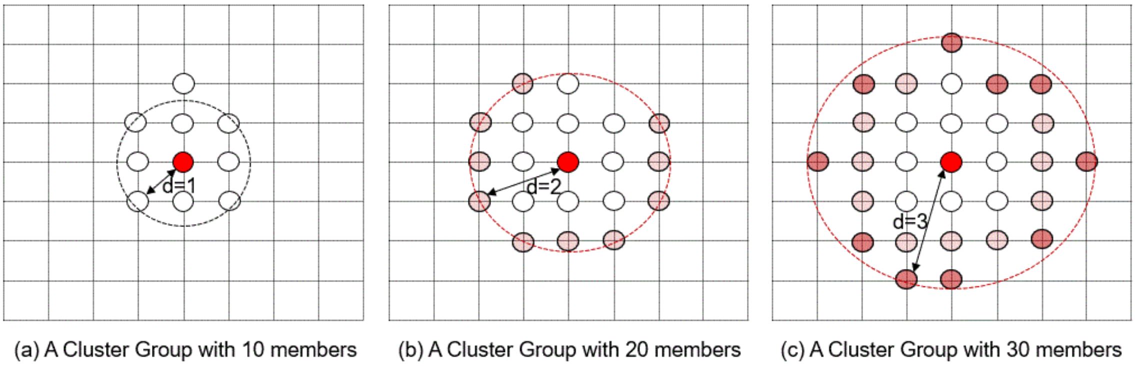


Fig 8. An Example of a Cluster Group Composed of Members Within a Unit Distance.

The power consumption of CH nodes was compared for these different density cluster groups. To assess power consumption, we based our analysis on the number of data transmissions, data transfer volume, and transmission distance. We utilized equations 2) from the radio channel model mentioned in the previous section. To predict the battery consumption of CH nodes in the group, we make some assumptions based on Equation 2). First, we assume that a CH node consumes 50 nJ/timestep of energy when collecting data from each sensor node once. In addition, when electing a CH node, it needs to receive election signals from all member nodes in the group, which requires additional energy consumption. The power consumption of each group was estimated when the member node in the group transmits 1 bit of data to the CH node and the CH node receives 1 bit of data. When the CH node collects data from member nodes, each member node requires one transmission, but the CH node must receive from each member node, resulting in an increase in reception frequency proportional to the number of member nodes. The power consumption of the CH node was measured in terms of transmission frequency. The power consumption of member nodes increases proportionally with the distance from the CH node. Assuming that the CH node collects data from member nodes at regular intervals, group b) in **Fig 8** has twice the reception frequency compared to group a), and group c) has three times the frequency. Therefore, power consumption also increases proportionally. As the number of cluster members increased, **Fig 9** shows that the CH node's data collection frequency from members increased, resulting in a rapid reduction in battery life. The x-axis of **Fig 9** represents the battery consumption when all members within the cluster group transmit data to the CH node once, and the y-axis indicates the corresponding battery amount.

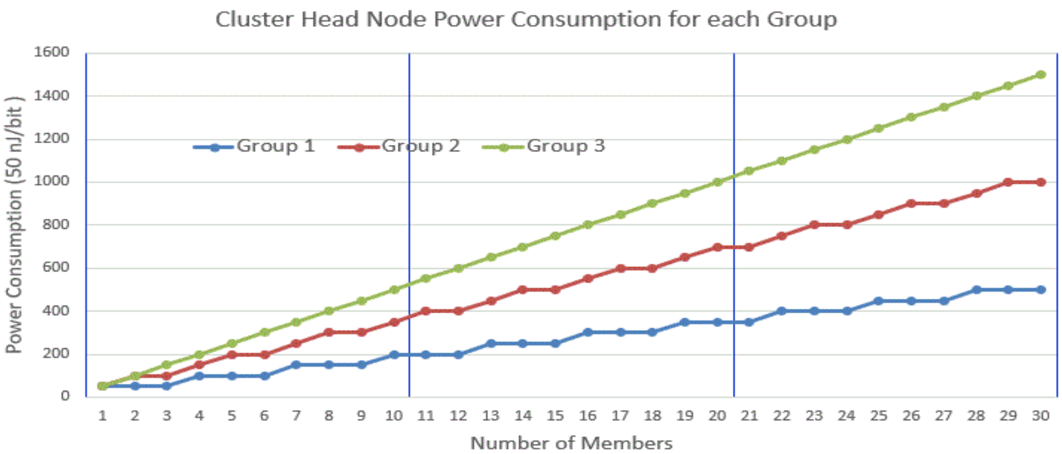


Fig 9. Power Consumption of CH Nodes Based on Cluster Density.

Fig 10 illustrates the power consumption based on the transmission distance when cluster member nodes transmit data to a CH node. The equation 1) was applied of the radio channel model mentioned in the previous section. In the figure, the blue represents the power consumption of each sensor node in Group 1, which has 10 member nodes. The red represents the power consumption of each sensor node in Group 2, which has 20 member nodes. The green represents the power consumption of each sensor node in groups where 30 member nodes form a single group. The power consumption of sensor nodes does not show significant differences based on distance. Therefore, it appears that the power consumption of sensor nodes is not greatly influenced by the cluster density.

The power consumption during the CH node election within the cluster also increases proportionally with the member density, and during the registration of member nodes within a unit distance for cluster formation, the power consumption increases proportionally with the member node density. As a result, compared to groups with lower cluster density, the overall lifespan of the cluster group is rapidly shortened in groups with higher member density.

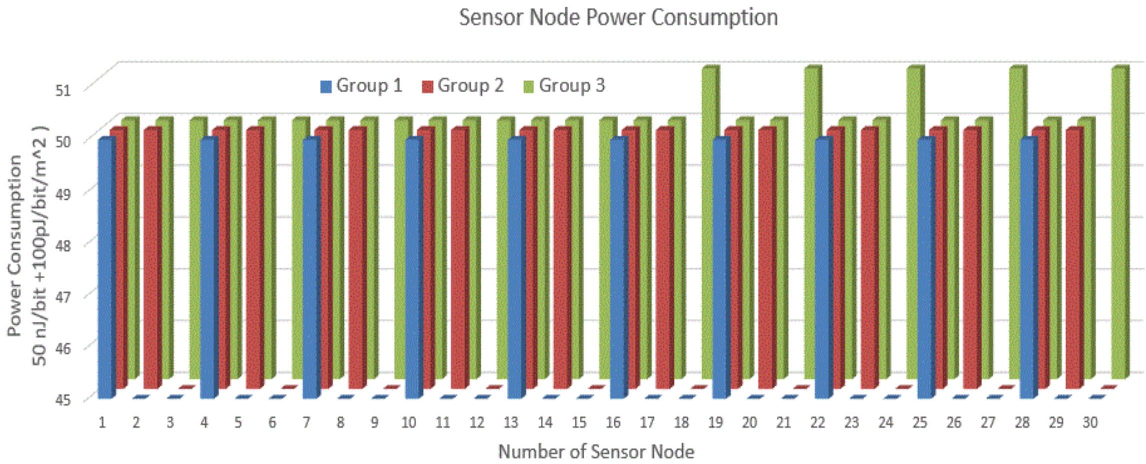


Fig 10. Power Consumption When A Sensor Node (SN) Transmits Data To A Cluster Head (CH) Node.

V. CONCLUSION

In this paper, we implemented cluster normalization using the mutual attraction of sensor nodes within a unit distance. In this paper, based on the mutual attraction between nodes, the node corresponding to the center of gravity of a cluster group is found and elected as the CH node. The purpose of cluster equalization is to reduce the number of cluster groups formed by abnormally large densities so that the lifetime of the network can be increased. In this study, the simulation results showed that a cluster uniformity improvement of about 20% was possible. The uniformity can be further improved by repeating the clustering step. Further research should be conducted to quantify the extent of network lifetime extension due to cluster group uniformity. For each cluster group density, we examined the power consumption of CH nodes and the power consumption during data transmission by member nodes, presenting the results in **Fig 7** and **8**.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

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There are no competing interests.

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